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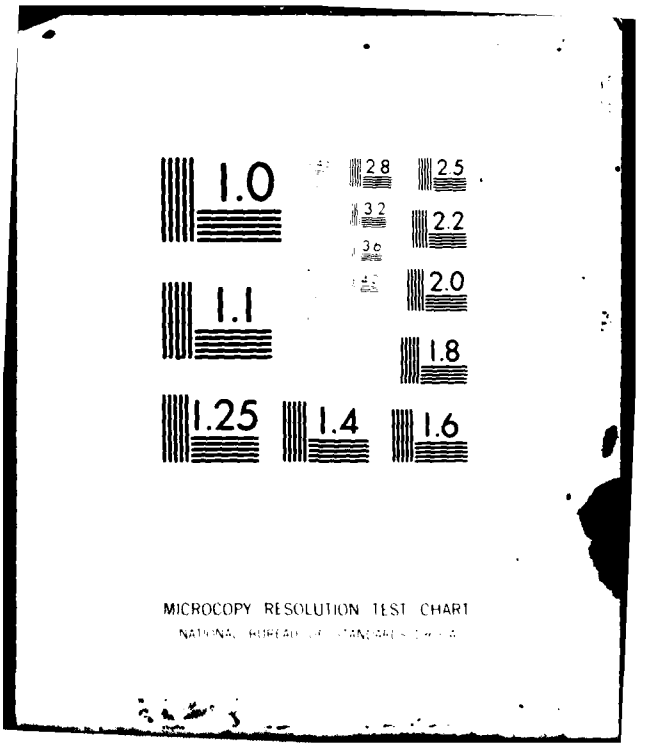
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Systems Technical Memorandum 58

ANALOGUE AND DIGITAL TIME DISPLAYS FOR MILITARY WRISTWATCHES

J.E. GORDON and B.A.J. CLARK

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ANALOGUE AND DIGITAL TIME DISPLAYS FOR MILITARY WRISTWATCHES

J.E. Gordon and B.A.J. Clark

Summary

The RAAF currently uses wristwatches with analogue (conventional clockface) displays. In response to a RAAF request, the arguments for and against using digital display wristwatches for military use were examined and an evaluation of two related US documents was carried out. One document, a US military specification for liquid crystal display digital wristwatches, includes most of the necessary safety and operational considerations. The other document, a questionnaire evaluation of military digital watches, appears somewhat unjustifiably biased in favour of digital wristwatches. It is recommended that for RAAF use, the US military specification should not be used in its present form as it leaves insufficient scope for technological improvements. Attention is drawn to alternative designs/displays for wristwatches, for example combination digital-analogue watches and electrochromic display watches.

POSTAL ADDRESS: Chief Superintendent, Aeronautical Research Laboratories, P.O. Box 4331, Melbourne, Victoria, 3001, Australia.

CONTENTS

1. INTRODUCTION

This memorandum was written in response to a request from the Director of Research Requests, RAAF, for a brief evaluation of a US Department of Defence military specification for digital wristwatches with liquid crystal displays (Ref. 1) and of a report describing the results of a questionnaire evaluation of digital watches for military use (Ref. 2).

2. EXAMINATION OF THE SPECIFICATION

The US specification for digital wristwatches described three classes of digital watches - a general purpose watch, a divers (sic) watch and an aircrew/navigator/shallow water divers (sic) watch. These watches differed with respect to the stopwatch duration, waterproof and shockproof limits, optional seconds readout, background lighting, and the number of numerals in the liquid crystal display. Overall, the specification appears to cover most of the points necessary. However, a few aspects appear in need of inclusion, expansion or modification before the specification should be used in procurement of military digital watches in Australia:

i) The replacement of the battery should not degrade the waterproofing characteristics of the watch.

ii) The dark viewing requirement in the US specification should be extended. The specification requires that the background luminance of either the incandescent, electroluminescent or self-luminous lighted background should allow the watch to be read in darkness by a person with 6/6 visual acuity at a minimum viewing distance of 12 inches (about 305 mm). The distance should be increased to about 600 mm to include operational situations in which it is inconvenient to move either the head or the arm in order to read the time, for example, a pilot flying with his left arm (with wristwatch) placed on the control wheel. Furthermore, specifying a near visual task in terms of Snellen distance acuity is inappropriate; in this context a Jaeger near vision chart acuity of J5 (achieved with spectacle correction if required) or the equivalent in the recently introduced Bailey-Lovie logMAR charts (Ref. 3) would be more suitable.

iii) Any Australian legal restrictions or safety recommendations on the use of radioactive substances in self-luminous displays ought to be examined (for example Ref. 4).

iv) The International System of Units (SI) should be used in an Australian specification.

In the specification it is recommended that the digital watch should have either a continuous self-luminous light source or an incandescent/electroluminescent lamp to backlight the time display for night viewing. After measuring the incandescent night light luminances of various makes of digital watches, the authors believe that the recommended luminance level for the incandescent light source, namely 0.1 cd/m² (0.03 ft L), is slightly low for easy reading of the display. It is difficult to suggest a more appropriate luminance level without experimenting with a military issue digital watch, although it is unlikely that the upper limit would need to be above 1 cd/m². It is also important that the display be lit more uniformly than is usually the case with a single incandescent source in one corner or at one of the short sides of the display. This would require either two incandescent light sources, one on either side of the rectangular display window, or a single light source situated at the top centre or bottom centre of the display. These suggested positions would appear to allow for a greater proportion of the night light output to illuminate the display.

3. EXAMINATION OF THE QUESTIONNAIRE REPORT

The evaluation report (Ref. 2) summarized the findings of a questionnaire survey of 425 personnel (predominantly military) who were issued with a modified 'Timex Marathon' model digital wristwatch which has a liquid crystal display. The conclusions of the report, in the opinion of the present authors, were somewhat over-generalized and biased in favour of digital wristwatches and appeared to discount important minority opinions. The answers to a number of questions indicated that there was not unanimous agreement; for example 15% of respondents experienced difficulty operating the buttons controlling the display functions, 44% found that the face crystal was easily scratched and an average of 9% of individuals rated the watch poorly on a visibility scale to estimate the clarity of the display image under different lighting conditions. Of greater importance was the acceptance of the digital format. Eleven per cent of the subjects indicated that they had difficulty in mentally adjusting to the digital display in calculating specific time in relation to the hour. It was stated that this difficulty was experienced both by navigators and pilots 'especially during flight when time compression is more severe'. It was also stated that these comments came largely from the older respondents to the questionnaire. These comments indicate that some persons may regard digital displays unfavourably, depending on the type of job or task, the individual's personal preference and/or age.

4. DISCUSSION

It is well established in ergonomics literature (for example, Ref. 5) that analogue displays provide quantitative information (that is, the indication of an exact numerical value) as well as qualitative information (that is, an approximate value, trend, rate of change or direction of deviation from a reference value). On the other hand, digital displays are a poor source of qualitative information. Also from a human engineering standpoint, the character legibility of digital matrix displays is poor. In these types of displays, the characters are formed from prepared matrices with resultant stylized block-shaped characters.

Attention is also drawn to various aspects of liquid crystal displays. There are three types of liquid crystal displays now commercially available (see Ref. 6). Dynamic-scattering displays were the first generation of liquid crystal displays to be produced. The second and present generation are twisted nematic liquid crystal displays and it is assumed that Reference 1 refers to this type of technology. There is now a third generation of improved liquid crystal displays which utilize a dyed phase-change effect. Some of the advantages of this new display include improved legibility and a wider viewing angle of ± 80° compared with ± 40° for the twisted nematic displays.

The display lifetime of dynamic scattering displays is 10 000 hours while the other two types of liquid crystal displays last over 50 000 hours (Ref. 6). Reference 1 specifies that the liquid crystal display life in the wristwatch should be 50 000 hours. This represents about 6 years and presumably would be acceptable as a guaranteed minimum,but not as a mean of a distribution with a large variance.

Bylander (Ref. 7, p.147) described some further precautions when using liquid crystal displays:

'1. Protect against freezing.
2. Avoid boiling and storage above 100°C.
3. Double images will result if a mirror reflector is used with dark numerals on a transparent background.
4. Temperature-controlled thin-film heaters are commercially available to stabilize displays at low temperatures. Their use can double the display cost.'

Of these the first could be a problem if the watch is exposed to very low ambient temperatures, or even to temperatures

just below freezing if the watch is not being worn at the time. Shanks (Ref. 6) noted that the operating range of the three current types of liquid crystal displays were all between - 10 to 80°C. The components of liquid crystals will segregate and solidify when exposed to very cold conditions, so that the display ceases to function until it is warmed up. At the lower end of the operating range, the display may have an unacceptably slow response. The second precaution is probably equally applicable to other kinds of displays and watches. The third appears to have been well recognised by manufacturers as diffuse rather than specular reflectors seem to be almost universal. For the fourth point, despite what has just been stated about slow response of liquid crystal displays at low temperatures, it seems that display heaters might be hard to justify in the Australian military environment.

The speed and accuracy with which one can mentally subtract times displayed on analogue and digital time displays and verbally report the results was investigated by Van Nes in 1972 (Ref. 8). The results of this experiment showed that for the determination of small time differences (less than 2 hours), subtraction of times was more accurate and quicker from two digital displays by comparison with an analogue-analogue subtraction or with a subtraction from one analogue and one digital display. Operational and perceptual subtraction errors involving misreading of the clock hand position were typical of the analogue-analogue subtractions. For the digital-digital subtraction the most common error was in mental arithmetic. Zeff (Ref. 9) found that digital displays were preferable to analogue displays for the task of logging time in digital form.

The combination digital-analogue watches now commercially available may represent a suitable compromise if the numerals in the combined time displays are of an adequate size for easy legibility. There are many types of combination displays already available, for example liquid crystal analogue displays of watch hands with digital time display, and conventional analogue displays with inserted liquid crystal digital displays. However, the presence of sheet polarizers as an inherent part of liquid crystal displays limits the total reflectance to something like that of light grey paint, so that the liquid crystal display is generally darker overall than a conventional analogue display with a white background. This is a particular problem at night.

Electrochromic display technology is currently being used in digital watch development and design (Ref. 10). These displays, which can for instance produce blue numerals on a white background, are claimed to be able to overcome an inherent problem of liquid crystal displays by providing a bright clear display over at least the whole range of angles from which a conventional analogue watch display can be read. The rapid loss of popularity of red light-

emitting diode displays in wristwatches in recent years ought to be regarded as an indication of the extent of change in display technology. It would therefore seem unwise to adopt a specification as narrow as Reference 1. Rather, a specification should specify performance in terms of visibility, accuracy, durability etc. and leave it to manufacturers to make the choice of technology required to meet the specified characteristics.

5. CONCLUSIONS

It is concluded that the US Department of Defence military specification for digital wristwatches appears to include most of the characteristics necessary to ensure compliance with military operational and safety requirements, although the specification allows little scope for technological advances. Examination of a questionnaire survey of digital watches for military use was found to be somewhat biased in favour of digital wristwatches and it appeared to unfairly discount a minority of respondents who found difficulty in accepting and/or using digital wristwatches.

Digital time displays may be preferable to analogue time displays in particular tasks requiring an exact quantitative representation of time. Analogue displays, in contrast, have the added advantage of providing a visual cue (clock or watch hand position) of the relationship between different times, thus providing both quantitative and qualitative information. It should be emphasized that individuals - because of their age, experience with digital or analogue time displays or their type of occupation - may differ widely in their acceptance and efficacy in using digital time displays. Attention is drawn to alternative designs/displays for wristwatches, for example combination analogue-digital display watches and electrochromic display watches, as these may meet with better acceptance by users.

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16.Abstract

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